Using optical image correlation to quantify the three-dimensional displacement field of historical events: Example from the 1959 Mw 7.2 Hebgen Lake earthquake.

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Motivation

• Optimise the OIC (optical image correlation) processing workflow for the historical photographs.
• Determine the 3-dimensional offset created by the 1959 Hebgen Lake earthquake.
• Quantify the full displacement field created by the Hebgen Lake earthquake and the off-fault damage on normal faults.
• Explore the effect of the factors such as lithology and fault geometry on the damage distribution in the extension setting.

Method

Input

Application of SfM techniques to the historical imagery

3D offset

Correlation

DEM generation

Orthorectification

Output

E-W displacement map

Vertical displacement map

NS displacement map

Results 1

Displacement maps are the result of the correlation between the 1947 and 1959 (top) and 1947 and 1977 (bottom) aerial photographs. A is the N-S component, B is the E-W component and C is the vertical component. The areas of the highest offset are concentrated on the two large faults, the Hebgen fault and the Red Canyon fault. This is in agreement with the previous observations. The earthquake-related movement was dominated by the dip-slip faulting which translates into a high offset in the N-S and vertical component while the E-W motion was negligible.

Results 2

To detect the 3-D displacement from the historical imagery, we apply an automatic processing chain which co-registers, orthorectifies and correlates the pre- and post-earthquake image sets:

1. Co-registration. Generation of the well registered image network from the pre- and post-earthquake photographs, utilizing SfM techniques.
2. DEM Generation. We use an image processing pipeline (ASP [1]) to create a high resolution DEM from the aligned stereoscopic images.
3. Orthorectification. The high-resolution DEM is used as a reference for the precise orthorectification. This process eliminates the effect of the topography and prevents any topographic residuals in the final correlation.
4. Correlation. To extract the displacement, the correlation process compares pixels from the left and right ortho-image. The output of this process is a horizontal disparity map with the N-S and E-W component.
5. DEM Differencing. The displacement maps are used to shift the pre-earthquake DEM to the post-earthquake position and subtract the pre-earthquake from the post-earthquake topography. The difference in elevation is interpreted as the vertical tectonic offset.
6. De-noising. To eliminate the radiometric noise caused by the vegetation cover, we apply a correction calculated by the random forest algorithm.

Results 3

At the new structures exposed from the 1947 and 1977 image correlation results. The vector field overlays the vertical displacement map and shows the historical movement of both faults. The direction of movement suggests that the faults are left-lateral and right-lateral strike-slip with the central block moving towards S-E. The profile across A-B shows a significant horizontal offset. The vertical movement is indistinct. This suggests that the movement on these faults was mostly horizontal.

Summary and Implications

• The workflow optimisation allows an automatic processing of the historical imagery.
• The precise and accurate co-registration is necessary for the extraction of the high-resolution surface offset.
• OIC allows us to collect full displacement field.
• Neglecting off-fault damage can have impact on the estimates of the earthquake parameters and the reconstruction of the earthquake models.
• High-resolution measurements of the surface offset caused by the dip-slip earthquakes improve our understanding of the off-fault damage distribution in the extension setting.
• Applying OIC to the historical earthquakes has the potential to expand the catalogue of the characterised events.

References and Acknowledgements


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